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A
CATECHISM
OF
ASTRONOMY;

BEING A
POPULAR OUTLINE
OF THE
PRINCIPLES AND LEADING FACTS OF THAT SCIENCE.

BY HUGO REID,
Lecturer on Natural Philosophy in the Liverpool Mechanics' Institution.

ILLUSTRATED BY ENGRAVINGS ON WOOD.

72

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PREFACE.

THE following outline of the Science of Astronomy is intended to convey a concise explanation of the more important phenomena and principles of that branch of knowledge, suitable to the general reader as well as for the instruction of youth. Though Astronomy, in its full extent, is a subject of a wide and complex nature, the leading results which it develops are simple, and may be comprehended within a moderate compass; it is hoped, therefore, that the following little treatise may afford a satisfactory sketch of some of the more interesting features of the science.

The singular phenomena which recent researches have discovered relative to the fixed stars, as well as the consideration that these are generally too slightly passed over in systems of astronomy, have induced the Author to insert a short notice in regard to them, which he trusts will enable the attentive student to survey the heavens with additional interest, and also assist him in discovering the places of the several planets.

In a work of this extent, where selection and condensation are essential, the Author hopes that the reader will agree with him in deeming those subjects which have been the most fully treated to be such as deserve the largest share of his attention.

EDINBURGH, *September*, 1841.

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CATECHISM OF ASTRONOMY.

Q. What is Astronomy?

A. Astronomy is the science which treats of the heavenly bodies:—describing their forms, magnitudes, distances, relative situations, motions, and actions upon each other.

Q. What do you mean by the heavenly bodies?

A. The Sun, the Earth, the Moon, and the Stars.

Q. What is the derivation of the term "Astronomy?"

A. It is derived from the Greek words Αστηρ (aster), *a star*, and Νομος (nomos), *a law*. Its literal signification therefore is, the law of the stars, or order of the stars.

Q. Is the division of the heavenly bodies into Sun, Earth, Moon, and Stars, a good one?

A. No; because it is not founded on any essential differences between these bodies. It is a popular arrangement, classing them simply as they appear to us.

Q. What would be a better classification?

A. Fixed Stars, and Solar System. The Solar System embraces the Sun, the Planets (including the Earth), the Satellites (including the Moon), and the Comets.

I.—OF THE FIXED STARS.

Q. What is meant by the Fixed Stars?

A. The fixed stars are those which do not sensibly change their positions *in relation to each other*.

Q. Is there any other mark by which the fixed stars can be distinguished?

A. They twinkle,—alternately contracting and extending their rays.

Q. What proportion do the fixed stars bear to the thers?

A. All the stars usually visible to the naked eye are fixed stars, excepting five,* and an occasional comet.

Q. What is known respecting the fixed stars?

A. Extremely little. We can judge of their *relative brightness,* we can determine their *least distance* from us, and we can ascertain their *apparent* motion round the earth.

Q. Have we no knowledge of their size?

A. None; for, they present no disc or surface whose breadth can be measured, even in the telescope, being seen by its aid, as by the naked eye, merely as brilliant shining points, but more bright and luminous. Thus, while they vary in apparent brightness, we are ignorant of their comparative distance, and also of their actual comparative brightness,—the only points that could enable us to form any judgment of their magnitude. The different magnitudes which they present to us may arise from their different distances, different sizes, or different degrees of brightness.

Q. What knowledge have we regarding their distance?

A. Solely that they are not at less than a certain distance. We cannot say how much beyond that the distance of any fixed star may be.

Q. How is this ascertained?

A. It is found that they give no parallax† with the diameter of the earth's orbit, a distance of 190 millions of miles; and therefore the nearest cannot be less than 19,200,000,000,000 miles, that is, 19 millions of millions of miles,—so very far from the earth, that light, which travels at the rate of 192,000 miles in a second, must require at least three years to come to the earth from the nearest fixed star.

Q. Has any conjecture been formed of the brightness of any of the fixed stars as compared with the sun?

A. Yes. It has been calculated from the great brilliancy of Sirius, the dog-star, combined with its enormous distance, that it cannot be less than twice, and *may probably* be fourteen times as bright as the sun.

---

* Mercury, Venus, Mars, Jupiter, Saturn.

† See Parallax, page 57.

Q. What is the supposed nature of the fixed stars?

A. They are conjectured to be suns, probably attended by planets revolving round them, to which they give heat and light, which they preserve in their orbits, and thus adapt as places of abode for living beings.

Q. What reason can be given in favour of this opinion?

A. Their influence on the solar system is so slight, whether imparting light or whatever it may be, that they cannot be regarded as subservient to the sun and planets; while their great distance shows that they must be of a magnitude like that of the sun, and that they shine by their own inherent light, not by reflecting the sun's rays.

Q. How are the fixed stars divided?

A. The fixed stars are arranged according to four different principles.

1. According to their brightness.
2. In constellations.
3. According to their situation in the heavens.
4. According to their kind, so far as that can be discovered.

1. *Division of the Stars according to their Brightness.*

Q. How are the fixed stars divided according to their brightness?

A. Into seven divisions, called *magnitudes,*—the brightest being termed of the first magnitude; the next in point of brightness, of the second magnitude; and so on.

Q. Is there any other designation given to them according to their apparent brightness?

A. Yes. The stars in each constellation are named according to the letters of the Greek alphabet,—the brightest being termed α (or alpha), the first letter of that alphabet; the next β (beta); and so on.

Q. How many are reckoned of the first magnitude?

A. About 20 altogether. Of these, SIRIUS, the dog-star, is the brightest.

Q. How many are there of the other magnitudes?

A. About 60 of the second magnitude, 200 of the th magnitude; about 1000 of the fourth magnitude; nearly 20,000 in all, including the seventh magnitu

Q. How many can be seen by the naked eye?

A. Seldom above 2000 are visible at a time. Th of the fifth magnitude and all the brighter magnitu may, on a clear night, be discerned without the aid telescope.

Q. How many of the first magnitude are visible Great Britain?

A. About eleven.

2. *Division of the Stars into Constellations.*

Q. What do you mean by a constellation?

A. A constellation, in astronomical language, signi a collection of a certain number of adjoining stars, parated from the others by an imaginary line, and cluded under one name, expressive of some figure wh the leading stars in the constellation are considered resemble.

Q. Give an example of some constellation.

A. In Fig. 1. next page, near the top, is observe cluster of stars disposed within the figure of a sm bear, which is surrounded by a line separating it fr the adjoining stars. The stars within that line form *constellation*, termed *Ursa Minor*, or the Little Be In the same figure are seen parts of other constellatio —the Great Bear (*Ursa Major*), the Drag (*Draco*), the Camelopard, the hand of Bootes, a the feet of Cepheus.

Q. How are the constellations divided?

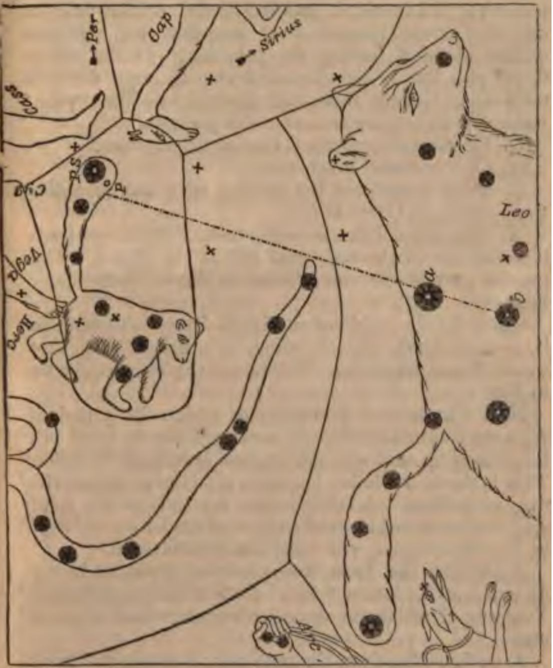
A. They are generally arranged in three region the *northern*, the *southern*, and those of the *zodiac*.

Q. Which are the northern constellations?

A. Those on the same side of the zodiac as the nor pole-star, lying around that pole-star.

Q. Which is the north pole-star?

A. The brightest star in the constellation termed Little Bear, at the tip of its tail. It is marked P the figure.



Q. Is there any easy mode of finding it out in the heavens?

A. Yes. The well-known seven bright stars, commonly called the *Bear*, the *Plough*, or *Charles' Wain*, give a ready method of discovering the north pole-star. These seven stars are shown at the bottom of the preceding figure, towards the right-hand side. If, when *these* seven stars are in any position, a line be drawn *through* the two farthest from the tail, and produced a direction *from* the limbs of the animal, that line pass close to the north pole-star. As no other st any considerable magnitude is near that line, this certain mode of finding the pole-star. In the ab figure, this line is represented drawn through the t stars *a* and *b* of the Bear, and passing close to the po star. These two are termed "the pointers."

Q. Of what magnitude is the north pole-star?

A. Of the second magnitude.

Q. Mention some of the leading stars and constell tions visible in Great Britain.

A. The Great Bear is well known. Its seven lea ing stars are in the body and tail of the figure. T greater part of this constellation is shown in the abo figure.

Upon the other side of the Little Bear, but nearer it, is an irregular cluster, which have been thrown in a male figure, Cepheus. The feet of Cepheus are show in Fig. 1.

Near Cepheus is a cluster, of which the princip stars are five in number, and arranged like the letter W but straggling, and with one angle shorter than the othe This is the constellation Cassiopeia, a female figure si ting in a chair. A straight line drawn from the pol star, and produced in the direction of the letters "Cass, in the above figure, will meet this constellation.

A straight line from the pole-star, produced in th direction of the letters "Per," leads to the constellatio Perseus, of which the three leading stars form a gent curve.

A straight line from the pole-star, through the wor "Leo," in the above figure, leads to a constellatio termed Leo, or the *Lion*, one of those in the zodia Its leading stars form a figure like a sickle or reaping hook.

A straight line from the pole-star, in the direction o the letters "Arc," passing near the last star in the tai of the Bear, leads to Arcturus, a very bright star of reddish colour, the principal star in the constellatio Bootes, or Huntsman, whose hand is seen in Fig. 1

A straight line from the pole-star, produced in direction of the letters "Herc," leads to the large constellation HERCULES.

A straight line from the pole-star, in the direction of the letters "Cyg," leads to CYGNUS, the *Swan*.

A straight line from the pole-star, through the letters "Cap," and perpendicular to the line of the pointers, leads to a very bright star, CAPELLA; the principal star in the constellation AURIGA, the *Charioteer*. Capella does not set in Great Britain, and is almost always visible in this country.

A straight line from the pole-star, in the line of the word "Vega," in the direction opposite to the line leading to Capella, leads to a very bright star, named VEGA. This star also never sets in Great Britain. Between the Great and Little Bear is seen the tail of the constellation "Draco."

Q. What are the constellations of the ZODIAC?

A. Those constellations through which the sun passes in his apparent annual path through the heavens. They are twelve in number, and termed Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces. The moon also, and the other planets are always found in some of the constellations of the zodiac.—See Seasons.

Q. What is their situation?

A. They form a zone or belt round the heavens, between the northern and southern constellations. Let the constellation LEO be found as described in page 10: then take a point in the constellation DRACO, half-way between VEGA and the POLE-STAR; and observe the distance of LEO from that point. All the other constellations of the zodiac will be at the same distance from that point as LEO.*

Q. Mention any bright and leading stars in the zodiac.

A. ALDEBARAN, in Taurus, of a reddish colour, and nearly due south from Capella.—CASTOR and POLLUX, two bright stars in Gemini, near each other, and south from the nose of the Great Bear.—Regulus, a bright star in Leo, almost due south from *the* nec the Great Bear.—Spica, in Virgo, due south from second last star in the tail of the Great Bear.—Antar in Scorpio, nearly due south from the convolution the body of the serpent, shown in Fig. 1. above.

---

* See "Six Maps of the Stars," published by the Society for the *Diffusion of Useful Knowledge*.

3. *Arrangement of the Stars according to their Situati in the Heavens.*

Q. What is the use of this arrangement of the stars

A. To define their precise relative situation.

Q. Explain how this is done.

A. The surface of the heavens is regarded, as it ap pears to us, as a concave sphere; and an infinite num ber of imaginary lines, crossing each other, are suppose to be drawn upon it. These lines are divided into de grees, numbered from certain fixed points: and b observing the situation of any star on these lines, wher two of them cross each other, its position can be de fined with great precision.

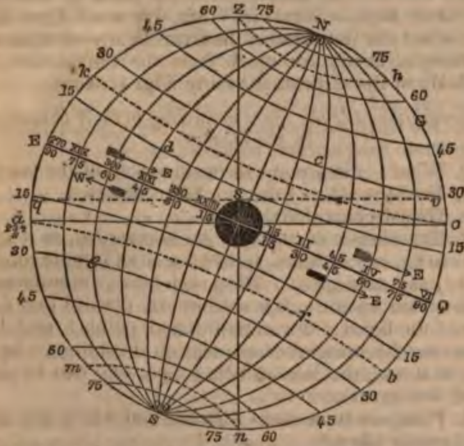
Q. What are those lines termed, and where are th fixed points taken?

A. This is illustrated by the following figure.

This figure represents the sphere of the heavens, wit the earth (the small black globe) in the centre. Tw fixed points in this sphere are taken, one, N, close t the pole-star, and termed the *Northern Pole of th Heavens;* and another, S, exactly opposite to the first and termed the *Southern Pole of the Heavens.* A serie of circles is supposed to be drawn round the sphere passing through these two points, and termed *hour-circles,* as NES, N*e*S, N*d*S, N*c*S, N*r*S, NQS. Anothe series of circles crosses the *hour-circles* at right angles This series is constructed by drawing the circle EQ termed the *Equinoctial* (and necessarily represented by a straight line in the figure) round the sphere, at equal distances from each pole, and then making an infinity *of circles parallel* to the equinoctial, as Zh, ko, ab, mn *&c. These are termed parallels of* declination.

Q. How are these circles divided?

Fig. 2.



A. Each is divided into 360 equal parts, termed *degrees:* and usually marked °, as 67°, 67 degrees—each degree is divided into 60 equal parts, termed *minutes*, and marked ′, as 59′, 59 minutes: and each minute is subdivided into 60 equal parts, termed *seconds*, and marked ″, as 43″, 43 seconds. Thus a point at 67 degrees, 59 minutes, and 43 seconds, would be shortly expressed, 67° 59′ 43″.

Q. How are the different *hour-circles* distinguished, so that it can be precisely pointed out which is referred to?

A. All the hour-circles, it will be observed, cross the equinoctial EQ; and this circle is divided as described above. Each hour-circle, therefore, is named according to the point in the equinoctial—that is, the degree, *minute*, and second—which it crosses.

Q. What point in the equinoctial are its degrees numbered from?

A. From the part where it is crossed by the hour-circle, which passes through the first point of the sign Aries, termed the *Equinox*.—See Seasons. The numbers *above* the Equinoctial line in Fig. 2. are alone to be attended to at present.

Q. What is the distance of any hour-circle from that point termed?

A. Its Right Ascension: and every point in each hour-circle has the same right ascension.

Q. Where is this point in the above figure?

A. In the middle of the line EQ, where it is marked 360. The degrees of right ascension are reckoned from that point towards the right, or *Eastward* in the heavens. In this figure, an hour-circle is marked at 15, 30, 45, 60, 75, and 90 degrees. Then, from 90 to 270, or 180 degrees, are on the other side of the sphere, and not seen in the figure. From 270 to 360, an hour-circle is again seen crossing the equinoctial at 285, 300, 315, 330, 345, 360, the last of which is at the point from which we started.

Q. I only observe each alternate number you have just named. Roman numerals occupy the intermediate spaces, *above* the line EQ.

A. Yes. The distances from the equinox are reckoned either in degrees or *hours*; each hour consisting of 15 degrees. In the above figure, the distances are expressed alternately in hours and degrees,—II hours, or 30°,—IV hours, or 60°. Hours are marked $^{h.}$ and divided into 60 minutes, marked $^{m.}$ when contracted.

Q. Give an example.

A. The point *c* in the above figure is in the hour-circle, N*c* II S. Its right ascension is therefore 360 II, the distance from the equinox to the point II, where its hour-circle crosses the equinoctial—that is, 30 degrees, or two hours.

Q. How are the different *parallels* of *declination* distinguished, so that any one of them can be precisely *referred to?*

A. By their distance north or south from the equinoctial. The hour-circles are divided into 360 degrees

Of these, one-half, 180, lie on each side between the north and south poles. Of these 180, 90 are *north*, between the equinoctial and the north pole; and 90 *south*, between the equinoctial and the south pole. Each parallel is therefore named according to the number of these degrees it lies north or south of the equinoctial.

Q. What is the distance of a parallel from the equinoctial termed?

A. Its *declination, north* or *south;* and every point in each parallel has the same declination.

Q. Give an example.

A. The point *d* is in the parallel which lies 15 degrees from the equinoctial, as seen on both sides, where it meets the hour-circle NESQ. Its declination therefore is 15 degrees north.

Q. How then would you express the precise position of the points *c*, *d*, *e*, and *r*?

A. The point *c* would be said to be in *right ascension* 30°, or 2 hours, and 30° *north declination;* the point *d* in *right ascension* 315°, or 21 hours, and 15° *north declination;* the point *e* in *right ascension* 300°, or 20 hours, and *south declination* 30°; the point *r* in *right ascension* 45°, or 3 hours, and *south declination* 23½°, or 23° 30′. R. A. expresses right ascension—D. S. declination south, and D. N. declination north.

Q. Mention the name of some leading stars in or near the equinoctial.

A. The most northern of the stars which form the belt of ORION is on the equinoctial. Procyon, of CANIS MINOR (the lesser dog), is only about 5° north of the equinoctial. Spica, the brightest star in the constellation VIRGO, is only 10° south of the equinoctial: and Altair, in the constellation AQUILA, is about 8° north of the equinoctial.

Q. Mention the right ascension of several leading stars.

A. The hour-circle that passes through the equinox, termed the *equinoctial colure*, crosses the brightest stars *in the* constellations CASSIOPEIA and ANDROMEDA: *Capella* is in north declination 46°, and right ascension 76°. Aldebaran is in north declination 16°, an

right ascension 66°. Algol, of PERSEUS, is abou
declination 40°, right ascension 45°, or 3 hours. R
is in right ascension 150°, or 10 hours; Arcturus, i
ascension 212°, or about 14 hours; Vega, in right
sion 277°, or about 18 hours; Altair, in right asc
296°, or nearly 20 hours; Sirius, in R. A. about

Q. Are the places of the planets ever expres
this manner in the almanac?

A. Yes. The sun's declination and right asc
and also those of the planets, are expressed in thi
In Oliver and Boyd's New Edinburgh Almana
White's Ephemeris, these are given. Thus,
former almanac for 1841, the situation of the
Venus on the 1st November is Dec. S. 2° 12′ (d
tion south two degrees twelve minutes), and R. A
37 m. (right ascension twelve hours thirty-seve
utes). This is very near Spica, the brightest
the constellation VIRGO, and nearly in a line b
that star and Regulus, the brightest star in LEO.

4. *Arrangement of the Stars according to other*
ences than their apparent Brightness or Situa

Q. How are the fixed stars divided when cla
according to other differences than their situati
apparent brightness?

A. Into, 1. Ordinary Fixed Stars. 2. Tem
Stars. 3. Variable Stars. 4. Double Stars. 5. N
6. Clusters of Stars.

Q. Which are the *ordinary fixed stars?*

A. Those which present the ordinary appeara
stars, and which, so far as can be discerned by th
scope, do not vary sensibly in brightness or sit
such as VEGA, CAPELLA, ARCTURUS, &c.

Q. What do you mean by *temporary stars?*

A. Stars which appear for a limited time, an
disappear entirely. Many stars given in old cata
are not to be seen now; and on several occasi
various parts of the heavens, new stars have su
appeared and disappeared, shining with various
of brilliancy during their short career.

Q. What do you mean by *variable stars?*

A. These are distinguished by varying in their brightness; undergoing a regular alternate increase and diminution in their lustre.

Q. Mention any variable star, with the phenomena it exhibits.

A. The second star, β, in the constellation PERSEUS, named ALGOL, is a variable star: it is generally visible in Great Britain. It may be found by drawing a line from the pole-star in the direction of the letters "Per," in Fig. 1 above, and passing through the extremity of the toe of CEPHEUS, as shown in that figure. In that direction, and at the same distance from the pole-star as VEGA, this singular variable star may be found.—As an additional aid to find Algol, it may be mentioned, that it is just on the margin of the milky way, on the side of it furthest from the *pole-star.* Its right ascension and declination are given at the top of page 16.

Q. State the time and extent of its variation.

A. "It is usually visible as a star of the second magnitude, and such it continues for the space of 2$^{d.}$ 14$^{h.}$, when it suddenly begins to diminish in splendour, and in about 3½ hours is reduced to the fourth magnitude. It then begins again to increase, and in 3½ hours more is restored to its usual brightness, going through all its changes in 2$^{d.}$ 20$^{h.}$ 48$^{m.}$, or thereabouts. This remarkable law of variation appears strongly to suggest the revolution round it of some opaque body, which, when interposed between us and Algol, cuts off a large portion of its light; and this is accordingly the view taken of the matter by Goodricke, to whom we owe the discovery of this remarkable fact, in the year 1782."—*Herschel.*

Q. What are *double stars?*

A. Two stars placed so near each other as to appear only one to the eye or ordinary telescopes, are in some instances found to have a regular progressive motion round each other. Where this is the case, the stars are termed *double* or *binary.*

Q. By whom was this interesting discovery made?

A. By Sir William Herschel, towards the close of the last century,—first distinctly announced in papers read to the Royal Society in 1803.

Q. Has the period of a complete revolution in the case of any of these double stars been determined?

A. Yes. In CASTOR, the leading star in the constellation GEMINI, which is one of these *binary stars,* the revolution is completed in 252·6 years; Castor is the most northern of the two stars usually termed Gemini or Twins. In a binary star in CORONA BOREALIS, the orbit is completed in 43·4 years,—a complete period having in this instance been gone through since the discovery by Sir William Herschel.

Q. What inference has been drawn from the phenomena of binary stars?

A. Motion, and revolution in an orbit, seem to indicate, that, among the stars, the same laws of motion and gravitation prevail which we find in our own system.

Q. What do you mean by *nebulae?*

A. Faintly luminous objects, occasionally consisting of clusters of stars; but in some instances of an apparently thin cloudy mass, with the luminosity in some cases becoming more intense towards the centre,—of that thin fleecy appearance observed in the tail of a comet.

It has been conjectured that these latter nebulae may be aerial matter in the process of condensation into stars, that is, into suns with their attendant planets.

Q. What do you mean by *clusters of stars?*

A. In some situations, a number of stars are found gathered close to each other, in isolated groups apart from the others. Such a collection is termed a *cluster,* and is generally supposed to belong to some system separate from the general body of the stars.

Q. Mention some of these clusters.

A. The MILKY WAY, the PLEIADES, COMA BERENICES. The first owes its light to myriads of stars closely set together, of which it is found to be composed.

Q. *Are the* stars supposed to be scattered indiscriminately *through* the heavens, or arranged according t *finite order?*

A. It is considered that they are set according to some definite plan, of which glimpses have begun to be obtained. Our star, the sun, is believed to belong to that cluster which forms the milky way, being placed near the middle of it.

II. THE SOLAR SYSTEM.

Q. What is meant by the SOLAR SYSTEM?

A. Certain of the heavenly bodies are found to form a system by themselves, connected with the sun, and apart from the others. The sun and these together form *the Solar System*, so called from "*Sol*," the Latin word for "the sun."

Q. Which of the heavenly bodies compose the solar system?

A. The SUN, the PLANETS with their *Satellites*, and the COMETS.

Q. What connexion is there between the sun and these bodies?

A. The planets and comets revolve round the sun, as their centre, in regular periods of time, are preserved in certain determinate orbits by his action, and receive light and heat from him; while the satellites revolve round some planet, are carried with it round the sun, and also receive light and heat from that luminary.

Q. Which are the PLANETS?

A. Those stars which do not remain in one spot, but have a regular motion through the heavens. They are therefore termed *planets*, from the Greek word πλανητὴς, signifying *a wanderer;* being so named in contradistinction to the fixed stars, which preserve their relative positions unchanged.

Q. What are they?

A. The planets are worlds like our earth, moving like it round the sun, from west to east, in orbits nearly circular. They are opaque, and dark in themselves, but shine by reflecting the light which they receive from the sun. It is most probable that, like the earth, they serve as abodes for animate beings.

Q. Enumerate the planets.

A. The planets are eleven in number, viz. MERCURY, VENUS, the EARTH (Tellus), MARS, VESTA, JUNO, CERES, PALLAS, JUPITER, SATURN, and URANUS (Georgium Sidus, or Herschel).

Q. What are the SATELLITES?

A. These are smaller planets which revolve round some of the above eleven planets as a centre; such as our moon. They are also termed *moons*, or *secondary planets;* the eleven which revolve round the sun as a centre being termed *primary planets.*

Q. How many satellites are there in the solar system?

A. Eighteen. The Earth has one, Jupiter four, Saturn seven, and Uranus six.

Q. What are the COMETS?

A. Bodies which revolve round the sun, but in elongated ellipses, and not always in the zodiac, as the planets do; and do not appear to be of the same solid substance as the planets. They have often long luminous tails, which, being of a somewhat fleecy or hairy appearance, have given the name *comet* to this class of bodies, from the Greek word signifiying "hair."

Q. What forces preserve the planets, satellites, and comets in motion, and cause that motion to take the direction of their orbits?

A. Those bodies which revolve round another are actuated by two forces:—1. A *projectile, tangental,* or *centrifugal* force, which keeps them in motion, and of itself tends to make them break off from the orbit in a straight line (a tangent to that orbit), fly from the centre round which they have been revolving, and move on for ever in a straight line; and 2. An *attractive, central,* or *centripetal* force, which tends to draw the revolving body to the centre round which it revolves; and which, if alone acting, would soon precipitate the planets and comets on the surface of the sun, and the satellites on their primary planet.

Q. Is any thing known of the nature of the projectile force?

A. No. Its existence is inferred from the phenomena; but we are unacquainted with any particulars regarding its source or nature.

Q. Is any thing known of the nature of the attractive force?

A. This seems to be the same force which is in operation on our earth, termed *gravity*, or *attraction* of *gravitation*, which causes bodies to fall to the ground when left unsupported in the air, which makes them exert a pressure there, gives them the property we call *weight*, and which causes a body thrown up or along in the air soon to come to the ground.

Q. What circumstances regulate the force of this power—the attraction of gravitation?

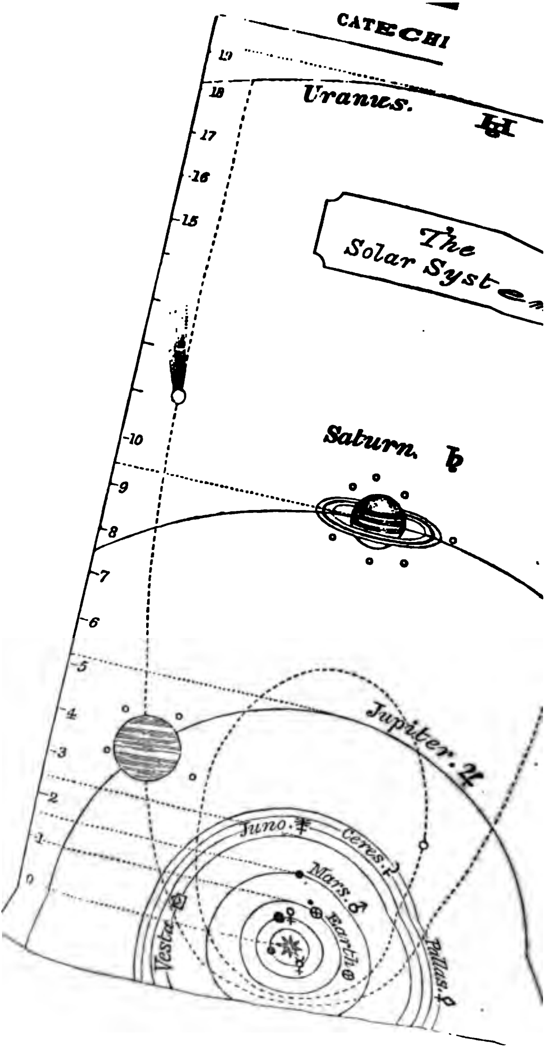
A. Two,—the quantity of matter, and the distance. Its force is *directly as the quantity of matter, and inversely as the square of the distance.* If the quantity of matter in a body be double that in another, it will exert a double attractive force. If its distance be double, it will exert, not one-half, but one-fourth, of the attractive force. If two equal bodies be at distances from another which are as 1 to 3, the attraction they exert towards that body will be *inversely* as the squares of 1 and 3, that is, *directly* as 9 (the square of 3) is to one (the square of 1), or

Attraction at		Attraction at				
1	:	3	::	9	:	1
2	:	5	::	25	:	4
2	:	1	::	1	:	4

—See note, page 29.

Q. Explain the figure of the solar system in page 22.

A. This figure exhibits the comparative distances and magnitudes of the planets. In order that the whole may be included in a small space, and the proportions preserved, parts only of the orbits of the more distant planets are given,—the sun, the centre of all, being placed near the bottom. Close to the sun is seen a small circle, the orbit of MERCURY, with the astronomical sign employed to indicate that planet: then the orbit of VENUS: then that of the earth: these are represented entire. Of the other orbits, part is cut off


CATECHI
19
18
17
16
15
10
9
8
7
6
5
4
3
2
1
0
Uranus. ♅
The
Solar Syst
Saturn. ♄
Jupiter. ♃
Juno. ⚵
Ceres. ⚳
Mars. ♂
Earth ⊕
Vesta
Pallas. ⚴

less of the orbit being shown, as its distance is greater: the name and sign of each planet are marked. The dotted straight lines, from the upper part of each orbit to the scale at the side, show the comparative distances of the planets from the sun and from each other. The first proceeds from the sun's centre; the second shows the EARTH's distance from the SUN, the third that of MARS, the fourth that of VESTA, and so on. The numbers at the side show at a glance the distances compared with the earth's distance from the sun, as the distance between any two adjoining numbers is the same as that from 0 to 1, which is the earth's distance. The curved dotted lines represent the orbits of comets. The smaller, which is complete, represents the orbit of the comet of Biela: the other is introduced to show the very elongated form which the orbits of comets sometimes assume. It must not be regarded as accurate in its proportions.

It must be observed, that while the proportionate distances of the planets from each other, and from the sun, are preserved, and also the proportions which the planets bear to each other in magnitude,—the following proportions *are not exhibited in the figure*, viz. the proportion of the magnitude of the sun to that of the planets, and the proportion of the magnitude of the sun and planets to that of the various orbits. The sun's diameter is about ten times that of Jupiter, and less than one-eightieth of the diameter of the orbit of the nearest planet, Mercury. The satellites also are too near.

1. The Sun (Sol), ⊙.

Q. What is the sun supposed to be?

A. A globe of immense magnitude, opaque in itself, but surrounded by a luminous atmosphere, from which emanate the rays that cause heat and light when they strike upon bodies.

Q. What is the distance of the sun from the earth?

A. A little less than 95,000,000 (ninety-five millions) miles is the *mean* distance.—But the earth is 3,000,000 *miles* nearer the sun in our winter than in our summer. —*See* Earth, and Seasons.

Q. What is the exact form of the sun ?

A. This body is not perfectly spherical
the planets, is flattened at the two opposite
poles. Its form is therefore that of an *obl*
like an orange.

Q. What is the diameter of the sun ?

A. The sun's diameter is a very littl
882,000 (eight hundred and eighty-tw
miles ; or 111½ times that of the equatoria
the earth.

Q. What is the bulk of the sun compar
of the earth ?

A. The sun is to the earth in bulk as
1 : that is, the sun is extended through 1,3
the space occupied by the earth.

Q. What is the weight or gravitating for
compared to that of the earth ?

A. The weight of the sun is to that of
354,936 to 1.

Q. How is it that the sun exceeds the ea
more in bulk than in weight ?

A. The density (the comparative quant
tating matter in the same bulk) of the sun
that of the earth. The sun's density is t
earth as 0·2543 to 1, or about one-fourth o
earth. The sun, therefore, being of much
terial than the earth, exceeds that body m
bulk than in weight.

Q. What is the force of gravity at the s
sun compared with that at the earth's surfa

A. The force of gravity at the surface
27·9 times that at the surface of the eart
therefore, which at the earth's surface wou
a spring to an extent indicating a weight o
would, at the surface of the sun, compress
as much as 27·9 pounds would at the earth

Q. Why is the force of gravity at the s
so little above that of the earth ?

A. Because the distance from the surfac
of the sun is so great, and the density of th

Q. Is the sun absolutely fixed, or has it some motion of its own?

A. The sun revolves upon its axis in a little more than twenty-five days, in a direction from west to east.

Q. How is this ascertained?

A. By observation of the spots on its surface. These are found to disappear on one side, while others appear on the opposite side, and disappear in their turn. The uniform progressive motion of the spots at the same rate, and in the same direction, can only be explained by a rotatory motion of the body of the sun. Further, the flattened form of the sun at the poles is a confirmation of its rotation, as we know that all bodies which rotate tend to assume this from.

Q. How does the sun's axis lie with respect to the plane of the ecliptic (the earth's orbit)?

A. The axis of the sun is not perpendicular to the ecliptic: it leans 7° 20′ from the perpendicular; forming therefore an angle of 82° 40′ with the plane of the ecliptic.

Q. Has the sun any other motion?

A. It is supposed that the sun is not fixed in one spot, but has a *proper motion*, as it is termed, through space, carrying the planets along with it.

Q. From what is this inferred?

A. It appeared to Sir William Herschel that the principal stars had a gradual motion *from* the constellation Hercules, and were becoming more open or spread out in that quarter—which he considered might be explained by a motion of the sun and planets towards that constellation.—But this, though it is highly probable that the sun has a proper motion of its own, must be regarded as a mere conjecture at present.

Q. Has the sun no other motions?

A. The sun appears to move daily through the sky, giving rise to night and day; and yearly through the constellations of the zodiac, causing its different degrees *of elevation* above the horizon at different periods of the *year.* But these are only *apparent* motions of the sun: *the* first caused by the rotation of the earth on its axis

—the second, by the earth's annual revolution round the sun.—See Earth, Seasons, &c.

Q. What appearance does the sun present when viewed through a telescope?

A. It presents a somewhat mottled appearance, with minute shady spots scattered through the luminous matter. Large dark spots, which are not permanent, and vary in size and form, are seen on its surface: these are termed *maculae:* they consist of a dark or black part in the centre, termed *nucleus*, with a surrounding part not so dark, termed *penumbra;* and in the vicinity of the spots, brilliant highly luminous streaks are seen: these are called *faculae*.

Q. Are the *maculae* found at every part of the sun's surface?

A. No. Only near his equator.

Q. What is the magnitude of the maculae?

A. They vary in diameter from a few hundred to upwards of forty thousand miles.

Q. What are the *maculae* supposed to be?

A. Various theories have been formed regarding them. It has been supposed that the surface of the sun is in a state of combustion, and that the spots are *scoriae*, *scum*, or ashy matter floating on the surface. They have been thought to be cavities in the body of the sun, the nucleus or dark part being the bottom of the cavity, and the penumbra or shady part its sloping sides, and they have been conjectured to be the smoke of solar volcanoes.

Q. What is the opinion most generally entertained at present respecting them?

A. That the spots are parts of the dark body of the sun exposed to view in consequence of breaks or gaps in the luminous atmosphere which is believed to surround the body of the sun. The *penumbra* is supposed to be caused by portions of an inner non-luminous atmosphere, in which the gap is not so wide as in the external luminous one; for when a spot disappears, the nucleus contracts, and is lost before the penumbra, as if the ga in the inner atmosphere had filled up first.

Q. Then the sun is supposed to have two atmosphe

A. Yes,—one transparent, but not luminous, next the body of the sun; and an external atmosphere, highly luminous, and at an elevated temperature, which is the source of the light and heat which the sun diffuses. The inner atmosphere, perhaps, rises into the other, and causes the mottled appearance above alluded to.

Q. What are the *faculae* supposed to be?

A. The elevated parts or ridges of waves in the luminous atmosphere.

Q. Why is the luminous matter at the sun's surface supposed to be in the aerial state?

A. Because the changes in the maculae show it to be subject to rapid and very violent agitations and ruptures, such as is probable only in aerial matter; and because the light that emanates from the sun is deficient in some of the properties that belong to light proceeding from a solid or fluid.

Q. Is any thing known of the source of the sun's light?

A. Nothing positive. It has been conjectured by some to be caused by minute particles of the sun's substance discharged from it, and by others to be caused by *vibrations* or *undulations* in a thin fluid diffused throughout space, which is supposed to be excited by the presence of luminous bodies, into undulations capable of giving rise to impressions of light. The latter theory is now more generally received.

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2. The Planets, with their Satellites.

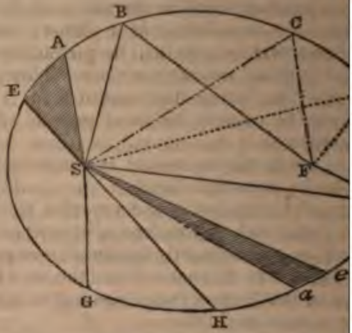
Q. What is the form of the orbits in which the planets revolve round the sun?

A. Elliptical or oval. "Each planet revolves in an ellipse, having the sun in one of its foci."

Q. What is an ellipse?

A. An oval figure of such a nature, that, two certain points, called its *foci*, being taken within it, the sum of two straight lines drawn from any point in the circumference to the two foci is always the same. See Fig. 4. next page.

Fig. 4.



Q. Describe this figure.

A. EBCDHG is the ellipse, and the poi two foci. Accordingly, if from the points straight lines be drawn to the foci, the two from any one of these points shall together length to the sum of the two drawn fron the other points in the circumference to the

Q. Then the planets are not always at tl tances from the sun?

A. No; they are at different distances parts of their orbits.

Q. Do the planets move with a uniform their orbits?

A. No,—they move more rapidly in p they are nearer to the sun. "The *radius* planet describes areas proportional to the equal areas in equal times."

Q. What is the *radius vector* of a planet

A. An imaginary straight line drawn fro *the planet*, supposed to remain fixed at the *follow the* planet in its course round the su *or contracting* according as the planet is *or nearer to the* sun.

Q. Illustrate the above law of equal areas in equal times by reference to the figure.

A. In Fig. 4. above, let S be the sun, and A, E, G, H, *a*, *e*, six successive positions of a planet: then the lines SA, SE, SG, SH, S*a*, S*e*, will be the radius vector of the planet in these several positions. Now, let it be supposed that the planet has moved from A to E, and from *a* to *e*, in exactly the same periods of time. It would then be found that the radius vector, in passing from SA to SE, has traversed the same space as in passing from S*a* to S*e*,—or that the shaded area SAE is equal to the shaded area S*ae*; that is, as expressed above, that the radius vector describes equal areas in equal times,—or that it describes areas proportional to the times. In like manner, if the area SEG be equal to the area SGH, then the planet will move from E to G in the same time as from G to H.

Q. In what direction do the planets move round the sun?

A. From west by south to east.

Q. Is there any relation between the distances of the lanets and the periods in which they revolve round he sun?

A. Yes. "The squares of the periodic times of the lanets are proportional to the cubes of their mean istances from the sun,"—that is, the square* of the lays any planet takes to go round the sun, is to the quare of the days any other planet takes to go round he sun, as the cube* of the distance of the first planet rom the sun is to the cube of the distance of the second lanet from the sun; or, in the case of Mercury and he earth,

$$\begin{array}{ccccccc} \text{square of} & & \text{square of} & & \text{cube of} & & \text{cube of} \\ 87 & : & 365 & :: & 37 & : & 95 \end{array}$$

The first number expresses the number of days occupied by Mercury in its revolution round the sun;

---

* The square of a number is the number produced by multiplying hat *number by* itself: the cube of a number is the product which is und *by multiplying* it *twice* by itself. Thus 9 is the square of 3, 27 e *cube of* 3; 4 is the square of 2, 8 the cube of 2; 25 the square of 125 the cube of 5.

the second, the number of days th
round the sun; the third, the distan
the sun in millions of miles; the fou
the earth from the sun in millions of

Q. Have the planets any other moti
sun?

A. All the planets have a constant
in a direction from west to east, like th
ning. The line about which they turn i
and its extremities are termed *poles.*

Q. How is this ascertained?

A. Usually by observing the motion
their surfaces, except in the case of the e
cess of ascertaining the time of the earth'
be described afterwards.

Q. How is it known that the planets a
not self-luminous.

A. Whatever side of a planet may be tur
us, we only see that part of that side which is
by the sun: the remainder of the half tha
towards us, and which is not enlightened by
not seen.

Q. What is the form of the planets?

A. Globular, but not perfectly spherical, b
tened more or less at the poles, like an orange.
are not *spheres,* but *oblate spheroids.*

Q. What is the cause of the planets assumi
peculiar form?

A. Their rotatory motion round their axes.

Q. How does this operate in causing the flatteni
the poles, and bulging out at the middle regions?

A. In consequence of the rotatory motion, the
at the surface have a tendency to fly off, and would
so were the motion sufficiently rapid, and the parts
held together by any firm force. But they are retai
by the force of the planet's attraction, acting in the
rection of the radius, from the centre towards the
cumference. Accordingly, under the influence of th
two forces, they take a middle course, which, by
composition of forces, brings them along the surf

from the poles towards the middle regions, and causes an accumulation in that quarter.

Q. Then, why are the waters, which are loose and moveable, not accumulated about the middle regions of the earth's surface, and the polar regions left dry?

A. Perhaps, from the land itself being worn down by the action of various disintegrating forces, rendered loose and moveable, and diffused through the waters, from which it subsides and fills up the lower parts,—or, possibly, because the earth assumed this form before there was any solid matter upon it, while it was all in the fluid state.

Q. How does the rotation of a planet influence the force of gravity at different parts of its surface?

A. It lessens the force of gravity in the middle regions.

Q. Explain how this takes place.

A. This occurs from two causes:—1. Wherever there is rotatory motion, the parts furthest from the axis will move most rapidly, and have the greatest tendency to fly off. The force of gravity, therefore, will be most resisted at those parts, and will produce a less effect,—less, by the amount of the centrifugal force,—and accordingly it is found, that a body weighs less or produces less downwards pressure towards the middle regions of the earth's surface than near its poles. 2. The oblate form which the rotatory motion imparts to the planet, also diminishes the force of gravity towards the middle regions, the parts there being further from the centre.

Q. How could this difference in the force of gravity at the poles and middle regions of the earth be shown?

A. Either by a spring balance, or by the pendulum. It would be found that any given weight would produce a greater effect upon a spring balance, according as it was brought nearer to the poles, its gravitating force becoming greater. The pendulum would vibrate or make its oscillations more rapidly the nearer it was to *the poles*: showing that the force of gravity increases *in that direction.*

Q. Are the planets observed in all parts of the heavens, or only in certain definite regions?

A. The planets are seen only in a particular zone or belt of the heavens, on each side of the line of the *ecliptic* (the earth's path through the heavens). This zone is termed the ZODIAC: see page 11, and page 64. The planes of the orbits of the planets are not coincident, but they are not much inclined to each other.

(1.) *The Planet Mercury*, ☿.

Q. Where is this planet situated in the solar system?

A. It is the nearest of all the planets to the sun, so far as is yet known.

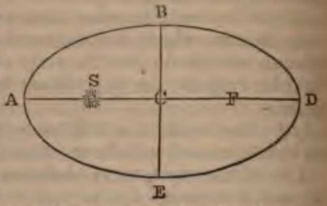
Q. What is the mean distance of Mercury from the sun?

A. About 37,000,000 (thirty-seven millions) miles.

Q. What is the form of the orbit of Mercury?

A. Rather an elongated ellipse. His *excentricity* (the distance from the centre of the ellipse in which a planet revolves to the focus) is more than a fifth of his mean distance from the sun. He will thus be at one time 2-5ths of his mean solar distance nearer to the sun than at another.—See Fig. 5., in which ADBE represents an ellipse, S, F, its foci, C its centre. AD is termed the *major axis* of the ellipse, BE, the *minor axis*. Then the distance from S to C, or F to C, is the excentricity: and if S represent the sun, it is evident that a planet is further from the sun at D than at A, by the distance S F, that is, twice the distance from the sun to the centre, or twice the excentricity.

Fig. 5.



Q. What is the diameter of Mercury?

A. A little less than 3200 miles,—more correctly, 3174 miles. It is the smallest of the planets, excepting the asteroids.

Q. In what time does Mercury revolve upon his axis?

A. In 24 hours, 5 minutes, and a few seconds.

Q. In what time does Mercury complete his course round the sun?

A. In 87 days, 23 hours, 25 minutes,—nearly 88 days.

Q. At what rate does Mercury move in his orbit?

A. At the amazing rate of 30 miles in a second, or 1800 miles in a minute.

Q. Can Mercury be seen by the naked eye?

A. Yes. But seldom, and only for a short time.

Q. Why is this planet seen so rarely and so briefly?

A. Because he is so near the sun, that he is always in that part of the sky close around the sun, and his inferior light is lost amid the sun's rays. Mercury never departs above 29 degrees from the sun.

Q. At what times can Mercury be seen?

A. Only for a little before sunrise, and a little after sunset.

Q. Does Mercury ever pass directly between the earth and sun?

A. Occasionally. He then appears as a black spot traversing the surface of the sun,—which is termed a *transit of Mercury over the sun's disc.* This is a rare phenomenon, however.

Q. Why does this transit occur so seldom?

A. Because the plane of the orbit of Mercury is not coincident with that of the earth,—being one-half above the plane of the orbit of the earth, and the other half below. Consequently the sun, earth, and Mercury, can only be in the same straight line, when the two latter are in the line of intersection of the planes of their orbits.

The transit of Mercury occurs at intervals of 6, 7, 13, 46, and 263 years.

Q. How much is the orbit of Mercury inclined to the ecliptic (the earth's orbit)?

A. About seven degrees. That is, there is an angle *of seven degrees* at the intersection of the planes of the *two orbits.*

Q. Does Mercury appear always of the same size and orm?

y the sun ; and as different quantities o urned towards us, we see different amou uminated half at different times.

Q. Of what size does the sun appear a

A. About three times the diameter whi o the earth,—correctly, as 82½ to 32.

Q. What proportion of light and heat eceive from the sun ?

A. About seven times as much as the e he heat and light will be seven times gr *o far as these depend upon the sun's rays*

(2.) *The Planet Venus,* ♀.

Q. Where is Venus situated in the sola

A. The orbit of Venus lies between tho nd the earth : being the second in order

Q. What is the mean distance of Ve un ?

A. Less than 69,000,000 (sixty-nine m —about 68,590,000 miles.

Q. Does her distance from the sun var

A. No ; her excentricity is only abo ean distance from the sun.

Q. What is the diameter of Venus ?

Q. Is Venus seen by the naked eye?

A. Yes; she is the most beautiful of all the planets, whence her name; and she appears to us as bright and large as Jupiter, which exceeds her very much in magnitude.

Q. At what periods is Venus seen?

A. Before sunrise and after sunset, being well known in the first case as *Phosphorus, Lucifer*, or *the morning star;* in the second, as *Hesperus, Vesper*, or *the evening star.* But she is seen for a much longer time before sunrise and after sunset than Mercury, departing much further from the sun than that planet can do,—namely, to a distance of forty-seven degrees (47°) from that luminary.

Q. Does Venus ever pass between the earth and sun?

A. Yes. But the transit of Venus over the sun's disc occurs seldom, for the same reasons assigned above for the rare occurrence of the transit of Mercury. The transits of Venus take place alternately at intervals of about 8 and 113 years. The last transit of Venus was in the year 1769. The next will be in 1874, and the next in 1882.

Q. Is not this phenomenon of great use in practical astronomy?

A. Yes. It has been taken advantage of to aid us in determining exactly the sun's distance.

Q. How much is the orbit of Venus inclined to the earth's orbit (the ecliptic)?

A. About three degrees, twenty-four minutes (3° 24′).

Q. Does Venus change in her apparent size and form?

A. Yes. She has *phases*, like Mercury and the moon, and for similar reasons.

Q. Of what size does the sun appear at Venus?

A. The diameter of the sun appears at Venus about one-half greater than at the earth,—correctly, as 44 to 32.

Q. How much greater is the sun's influence at Venus than at the earth?

A. About double.

Q. What angle does the axis of Venus make with the plane of her orbit?

A. An angle of only 15 degrees: that i leans 75 degrees from the perpendicular.

Q. What peculiarities in the constitution result from this great inclination of her axis

A. That there is a much greater diversity than prevails on the earth,—that the days longer where it is summer, and much short is winter,—that a larger proportion of the regi the poles have perpetual day or perpetual n that the middle or equatorial regions of Venu summers and two winters in each of her y Seasons.

(3.) *The Planet Earth* (*Tellus*), ⊕

Q. What position does the earth occupy i system?

A. The earth is the third planet from the orbit lying between those of Venus and Mar

Q. What is the distance of the earth from

A. The mean distance is a little less than (ninety-five millions) miles. The least dist earth from the sun is about 93,500,000 (ninet a half millions) miles: this position is terme *helion* (near the sun), and the earth is in its on the 31st of December. The greatest dist earth from the sun is about 96,500,000 (nin a half millions) miles. This position is term *helion* (from the sun); and the earth is in i on the 1st of July. Her excentricity is abo

Q. The sun must appear larger in Decem July?

A. Yes; in the proportion of 32½ to 31½.

Q. What is the diameter of the earth?

A. Its mean diameter is 7912·4 miles. from pole to pole, the diameter is 7899·17 is the shortest or *polar* diameter, or axis. through the widest part, the diameter is 792 this is the longest or *equatorial* diameter.

The difference between the longest and meters is 26·47 miles, 1-299th of the long

Q. What is the EQUATOR?

A. This is the circumference of the earth round its widest part. It is 24,926 miles in length.*

Q. How is the surface of the earth marked, in order to specify the precise position of any point?

A. In the same manner as the sphere of the heavens, as explained in pages 12—16: different terms, however, are applied to the various circles.

Let the large figure, page 13, represent the surface of he earth, NS the axis about which it rotates, N the orth pole, S the south pole, and EQ a circle drawn ound the earth at equal distances from the north and outh poles, that is, the equator. Then the circles, *Zh*, *o*, *q* 15, *ab*, *mn*, are termed PARALLELS OF LATITUDE; nd the circles, NESQ, N*e*S, N*d*S, N*c*S, &c., which ass through both poles, are called THE MERIDIANS of ny places through which they pass.

Q. What is the distance of a place north or south rom the equator termed?

A. Its LATITUDE, north or south. Thus the point *q* is in north latitude 15 degrees; the point *r* in south atitude 23½ degrees.

Q. What is the distance of a meridian along the equator termed?

A. Its LONGITUDE: east or west, as the case may be. Thus (looking now at the figures *below* the line EQ) the point *e* would be in west longitude 60°, as seen where its meridian crosses the equator; the point *r* is in east longitude 45 degrees.

Q. From what point on the equator are the degrees of longitude reckoned?

A. By the British, the longitude is measured from the point where the meridian of GREENWICH crosses the equator. On the earth the degrees of longitude are reckoned eastward and westward from the meridian of Greenwich, of course going only 180 degrees each way. —See the figures *below* the line EQ in the figure.

Q. What is meant by the HORIZON?

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* *The circumference of a circle is got by multiplying its diameter by 14159.*

A. This is the circle observed by a s
where the earth and sky appear to meet,
view around him: it is also termed the
zon. The *rational* or *celestial horizon* is a
to the above, also cutting the sky, but the p
passes through the centre of the earth.

Q. What is meant by ZENITH and NA

A. The zenith is the part of the heave
the head of the observer; the nadir, the
beneath him.

Q. Illustrate these terms on Fig. 2. pa

A. If the black globe in the centre
earth, and S a spectator on its surface,
zenith, *n* his nadir, *qv* the plane of his sen
ao the plane of his rational horizon.

Q. In what time does the earth turn u

A. In 23 hours, 56 minutes, 4·09 sec
56$^{m.}$ 4·09$^{s.}$—This is a SIDEREAL DAY.

Q. How is this reckoned?

A. From the time of a star being on th
a place till it returns to the same meridia

Q. What is meant by an object bei
meridian of a place?"

A. When the plane of the meridian o
being produced, would pass through an
object is said to be *on the meridian* of th
the object coming on the meridian is terme
to the meridian."

Q. What is meant by a SOLAR DAY?

A. The interval between two successiv
the sun to the meridian of a place.

Q. What is the length of the "solar da

A. The mean length of the solar day is

Q. Why is it more than the sidereal da

A. On account of the earth's motion r
The distance of the earth from the fix
great, that its position in any part of its
regarded as always the same, in referen
as is shown by its axis pointing to
all times. Hence, in reference to the

ay be looked on as not moving round the sun at all, it ever remaining in the same spot, rotating at a iiform rate on its axis, and therefore always returning any star in the same time. But the *earth's motion iwards in its orbit makes a material difference in its isition in relation to the sun.* Accordingly, after the rth has made a complete turn on its axis, and brought ie meridian of a place, on which the sun was at the mmencement of that rotation, to the same point again, iat meridian will not have reached the sun at the close ' the rotation; for, the earth has during that period oved onwards in its orbit as well as on its axis, and ust therefore, having in a manner moved *past* the in, move further round than the complete rotation to ing that meridian to the sun again.

Q. Explain the other lines in Fig. 2. page 13.

A. The dotted parallel *Zh*, near the north pole, is e *Arctic Circle*, 23° 28′ from that pole. The dotted rallel *ko*, is the *Tropic of Cancer*, 23° 28′ north of the uator. The dotted circle *ab*, is the *Tropic of Capri-rn*, 23° 28′ south of the equator. And the dotted rcle *mn*, near the south pole, is the *Antarctic Circle*, ° 28′ from that pole.

Q. What is the line *ao*, crossing the equator and uching the two tropics?

A. This is the ECLIPTIC, or the apparent annual path f the sun north and south of the equator at different eriods of the year.—See Seasons.

Q. At what rate do the equatorial parts of the earth's irface revolve?

A. They move round at the rate of 17·3 miles per inute, or 1038 miles per hour.

Q. In what time does the earth complete her course und the sun?

A. In 365 days, 5 hours, 48 minutes, 49·7 seconds -365$^{\text{d.}}$ 5$^{\text{h.}}$ 48$^{\text{m.}}$ 49·7$^{\text{s.}}$[*]

Q. At what rate does the earth move in her orbit?

---

[*] *The above is the tropical* year, and is the period usually stated as year. Perhaps it would be more correct to give the sidereal year, h *is longer by* 20 minutes 19·9 seconds; being 365 d. 6 h. 9 m. 9·6 s.

A. The mean velocity of the earth in her orbit is 18½ miles per second, or 1110 miles per minute.

Q. What is the diameter of the sun, as seen from the earth?

A. About half a degree, or thirty-two minutes—32′.

Q. What angle does the axis of the earth form with the plane of the ecliptic (the earth's orbit)?

A. An angle of 66° 31′ 20″ (sixty-six degrees, thirty-one minutes, twenty seconds),—that is, the earth's axis leans from the perpendicular to the orbit, or inclines towards the orbit 23° 28′ 40″ (twenty-three degrees, twenty-eight minutes, forty seconds). The extent of the inclination may be seen in Fig. 2. page 13. Let the line *ao* represent the plane of the earth's orbit: then NS will show the direction of its axis.

Q. What results flow from this inclination of the earth's axis?

A. The changes in the seasons, and in the length of night and day.—See Seasons.

Q. Does the axis of the earth preserve the same direction during the whole of its course round the sun?

A. Yes. It is always, in any situation, parallel to its position in any other situation. Thus, if in Fig. 2. the small black globe in the centre represent the earth, its axis pointing to N and S in the heavens; it will be found invariably to point to these same points.

Q. How may this be ascertained?

A. By observing the position of our pole-star, which corresponds to the point N in Fig. 2. If this star be watched, at whatever period of the year, or at any time of the night, and its situation ascertained in reference to any fixed object, as a tree, pillar, corner of a house, it will always be found in the same relative position to that object.

Q. What is the mean density of the earth?

A. The average density of the whole earth is about 5, compared to water as 1; but that of the parts at the surface is only about 2·5.

Q. How much is the force of gravity diminished at he earth's equator by centrifugal force?

A. About 1-289th. A body, therefore, from this cause alone, in the equatorial regions, will weigh 1-289th less than at the poles, where there is no centrifugal force.

Q. And how much is the force of gravity less at the equator than at the poles, from its greater distance from the centre, *i. e.* from the spheroidal form of our planet?

A. It is about 1-590th less from this cause.—The total difference in gravity at the poles and at the equator, therefore, is equal to the sum of these two quantities, or 1-194th; for $\frac{1}{289}$ and $\frac{1}{590}$ make $\frac{1}{194}$. Accordingly, a body which weighs any given quantity at the poles, as indicated by a spring balance, must be increased in weight by 1-194th part, to enable it to produce the same effect on the spring at the equator.

The Moon (*Luna*), ☽.

Q. What is the moon's situation in the solar system?

A. The moon is a satellite or secondary planet to the earth, round which it revolves, and with which it is carried annually round the sun.

Q. What is the mean distance of the moon from the earth?

A. About 237,000 (two hundred and thirty-seven thousand) miles.

Q. Of what size does the earth appear at the moon?

A. About 13 times larger than the moon appears to the earth.

Q. What is the diameter of the moon?

A. 2160 miles,—a little more than 1-4th of that of the earth.

Q. In what time does the moon revolve upon her axis?

A. In twenty-nine days, twelve hours, forty-four minutes—$29^{\text{d.}}\ 12^{\text{h.}}\ 44^{\text{m.}}$

Q. In what time does the moon revolve round the earth?

A. In $29^{\text{d.}}\ 12^{\text{h.}}\ 44^{\text{m.}}$,—the same time which she akes to turn upon her axis. This is the period from ne new moon to the next,—from the time of her being n conjunction with the sun till she comes to the same osition again,—and it is termed a *synodical* month, or er *synodical* revolution. Viewed, not with respect to e sun but to the stars, she is found to return to the ne star in 27$^{d.}$ 7$^{h.}$ 43$^{m.}$ This is termed a *sidereal* *periodical* month; and is the true period of the oon's revolution round the earth and on her axis.

Q. What results from the period of the moon's rotan on her axis being the same as that of her revolution und the earth?

A. That she always presents the same side to the earth: at that side is never totally dark, having one fortnight sunlight, and being illuminated by the earth the other rtnight; and that the other side has alternately a rtnight of sunlight and a fortnight of darkness.

Q. At what rate does the moon move in her orbit?

A. About 2-3ds of a mile each second, 37·9 miles in minute, or 2277 miles per hour.

Q. How much is the orbit of the moon inclined to e earth's orbit?

A. The plane of the moon's orbit forms with the liptic an angle of 5° 8′ 47·9″, so that the two planes e not very far from being coincident.

Q. How is the axis of the moon placed with respect the plane of the ecliptic,—the path in which the moon, ing carried along with the earth, moves round the sun?

A. The moon's axis scarcely leans towards the ecliptic all, being almost perpendicular to it. The angle it rms with the plane of the ecliptic is nearly a right gle, being 88° 17′,—thus leaning only 1° 43′ to the liptic. The moon, therefore, can have little or no ange in seasons, or in the length of the day.

Q. Does the moon's distance from the earth vary much?

A. Her excentricity is 1-20th of her mean distance om the earth, or about 12,000 miles. The difference etween her greatest and least distance is therefore about ,000 miles,—1-10th of her mean distance.

(4.) *The Planet Mars*, ♂.

Q. What is Mars' position in the solar system?

A. Mars is the next planet beyond the earth, his *it lying* between those of the earth and Vesta.

. *Is it not* sometimes termed a *superior* planet?

. *Yes; it is* the first of the superior planets. Thos of the planets which are nearer to the sun than the earth, namely, Venus and Mercury, are termed *inferior* ;—those which are farther from the sun than the earth, *superior*, as Mars, Saturn.

Q. What is the mean distance of Mars from the sun?

A. 144,500,000 (one hundred and forty-four millions five hundred thousand) miles.

Q. Does Mars' distance from the sun vary much?

A. Considerably more than the earth, but not so much as Mercury. His excentricity is less than 1-10th of his mean distance. The difference between his *aphelion* and *perihelion* is therefore about double that, or 1-5th of his mean distance from the sun.

Q. Of what magnitude does the sun appear at Mars?

A. The diameter of the sun, seen from Mars, is to that of the sun, as seen from the earth, as 21 to 32, or about 2 to 3.

Q. What is the relative proportion of the sun's influence at Mars and at the earth?

A. A little less than one-half, or as 12 to 27.

Q. What is the diameter of Mars?

A. About 4100 miles,—a little more than one-half of that of the earth?

Q. In what period does Mars revolve on his axis?

A. In about twenty-four hours and forty minutes—$24^{\text{h.}}\ 40^{\text{m.}}$

Q. In what period does Mars perform his revolution round the sun?

A. In 686 days, 23 hours and a half: moving in his orbit at the rate of about 15 miles in a second, or 900 miles per minute.

Q. How much is the orbit of Mars inclined to the earth's orbit?

A. Their planes are nearly coincident; the angle between them being one of only 1° 51′ 3″.

Q. What angle does the axis of Mars form with the plane of his orbit?

A. An angle of 61° 35′, about 2-3ds of a right angle, —*leaning* therefore from the perpendicular about 1-3d of a right angle, 28° 25′; a little more than the earth does. Therefore, there must be a considerable variety i

the seasons at Mars, more proportio
earth, though less than at Venus.

Q. What appearance does Mars presen

A. Mars, frequently being near t
pretty large and bright, though far l
Venus or Jupiter. He shines with
light, but dull and dusky-looking.

Q. What appearance does Mars presen

A. It exhibits phases, varying a
amount of the illuminated part which
us, which shows that Mars is not se
shines by reflecting the sun's light:—
around his poles are observed to be
the other parts, which, it is conjecture
accumulation of snow and ice around
to what prevails round the poles of t
and ice reflect light brilliantly, and
covered by these, as ours are, certainl
to the brilliancy observed in these regi

(5.—8.) *The Asteroids*

Q. Which are the Asteroids?

A. Four small recently discovered
between the orbits of Mars and Jupite
Juno, Ceres, and Pallas. They are s
telescopic, as they are not visible to th
can only be seen by aid of the telescop

Q. When and by whom were these pl

A. Vesta was discovered by Dr Olb
March 1807; Juno by Mr Harding, o
ber 1804; Ceres by Piazzi, on the 1s
Pallas by Olbers, on the 28th March

Q. State the leading circumstances
these planets?

A. Their distances are, in millions of
—Juno, 252—Ceres, 261—Pallas, 2
meters are variously stated, from ab
miles: Ceres has been said to be only
meter. The inclination of their or
are, *Vesta*, 7° 8′ 9″—Juno, 13° 4
Pallas, 34° 34′. They revolve rou

lowing periods—Vesta, 1335·7 days—Juno, 1592 days—Ceres, 1681 days,—Pallas, 1686 days. The excentricity of their orbits is considerable. Their signs are, Vesta, ⚶, Juno, ⚵, Ceres, ⚳, Pallas, ⚴.

Q. What peculiarities do these planets present?

A. 1. They are all extremely small, while, generally speaking, the planets rather increase in size as they are more distant from the sun.

2. They are all at nearly the same distance from the sun, viz. varying only from 223 to 262 millions of miles,—that is, the nearest to the sun is only about 1-5th of its distance (2-11ths) nearer than the most remote; whereas a very different law prevails with respect to the other planets,—the distance between two planets increasing in a very high proportion as they are further from the sun.

3. Their orbits are very much inclined to that of the earth, whereas the orbits of the other planets lie nearly in the same plane as the ecliptic. The orbits of Venus, Mars, Jupiter, Saturn, Uranus, are inclined at angles of from 0° 46′ to 3° 23′, and Mercury 7°; but the angles which the orbits of the asteroids form with the ecliptic are 7°, 10°, 13°, and 34°. Hence, while the other planets are always seen by us in the zodiac, the asteroids seldom appear there, being generally above or below it. They are, from this cause, sometimes termed *ultra-zodiacal.*

Q. To what speculations have these peculiarities in the asteroids led?

A. It has been conjectured that they originally formed *one planet,* which has been ruptured by some great convulsion, which has divided the *one* into four, and thrown the fragments out of the orbit in which they previously revolved, and which was nearly coincident with the ecliptic as in the case of the other planets, into orbits deviating considerably from the general order.

(9.) *The Planet Jupiter,* ♃.

Q. What position does Jupiter occupy in the solar system?

A. Jupiter is the next planet beyond the asteroids; his orbit lies between those of Pallas and Saturn,

Q. In what periods do these satellites revolv
Jupiter?

A. The first completes its orbit in 1 day, 1
28 minutes; the second, in 3 days, 13 hours,
utes; the third, in 7 days, 3 hours, 43 minu
fourth, in 16 days, 16 hours, 32 minutes.

Q. In what direction do the satellites revolv
their primary planet?

A. From west to east, as the moon does ro
earth, and the planets round the sun: Their orb
planes not much inclined to that of the planet's

Q. In what periods do Jupiter's satellites re
their axes?

A. In the same periods in which they revolv
him; obeying, in this respect, the same law
satellite, the moon.

Q. Have not the phenomena, arising from t
of Jupiter passing between his satellites and
been of considerable importance in practical astr

A. Yes. The eclipses of the satellites of
afforded the most accurate method of determi
longitude of places on the earth's surface: no
ever, in a great measure, superseded by lunar obse

Also, they have been the means of leading
great discovery, that the passage of light is no
taneous, but requires a certain time, and of dete
the rate of its motion.—It was found by Ro
Dane, in the year 1675, that when Jupiter w
the earth, the eclipses of his satellites took
little earlier than was calculated,—that, when
was remote from the earth, they occurred la
was calculated. This he explained by the supp
that light requires time for its transmissio
therefore, that we do not see very distant
mena at the actual moment of their occurren
sooner or later after it, according to the distanc
explanation of the variation from the comput
was afterwards confirmed by Bradley's great
of the aberration of light.

Q. What is the velocity of light, as dete
ese phenomena?

great as 192,000 miles in a second, or
00 miles in a minute.

(10.) *The Planet Saturn*, ♄.

hat is the situation of Saturn in the solar system?
is the most remote of the planets but one.
is between those of Jupiter and Uranus.
ppears between Mars and Jupiter in magni-
l shines with rather a dull light.
hat is the mean distance of Saturn from the sun?
out 904,000,000 (nine hundred and four mil-
les.
es his distance vary much?
nsiderably. His excentricity is more than
f his mean distance from the sun.
what magnitude does the sun appear at Saturn?
s diameter appears only 1-10th of the appa-
neter of the sun at the earth,—as 3⅓ to 32.
hat proportion of the sun's influence reaches

out 1-90th of that which we receive.
hat is the diameter of Saturn?
s equatorial diameter is about 79,000 miles.
r diameter of Saturn has been stated to be about
ss than the equatorial. Having a very rapid
on its axis, it is to be expected that Saturn,
ter, will be very much flattened at the poles.
what time does Saturn revolve on his axis?
10 hours 16 minutes.
what time does Saturn perform his revolution
e sun?
10,759 days, or about 29½ years:—moving in
at the rate of about 6 miles in a second, or
s per minute.
hat angle does the orbit of Saturn make with
's orbit?
ey are nearly coincident. The angle between
nly 2° 29′ 35″.
hat angle does the axis of Saturn make with
of its orbit?

A. A right angle, it is supposed. The axis then, being perpendicular to the orbit, this planet will, like Jupiter, have no change in seasons, or in the length of the day.

Q. What appearance does Saturn present when viewed through a telescope?

A. Stripes or belts are seen on his surface, as on Jupiter; but more faint than on the latter planet.

But the most remarkable feature observed about this planet is, the enormous RING by which it is surrounded. This singular appendage seems to be of solid matter, thin, flat, broad, and opaque. It is at a considerable distance from the body of the planet, and consists of TWO RINGS, one within the other.

Q. What are the distances of the rings from Saturn, and their dimensions?

A. The inner margin of the inner ring is about 19,000 miles from the body of the planet; and the breadth of this ring is 17,000 miles. The distance between the two rings is about 1790 miles; and the breadth of the external ring upwards of 10,000 miles. Their thickness is estimated at not more than 100 miles. The rings are nearly in the plane of the planet's equator, and rotate in their own plane in 10 hours and 29 minutes. The axes of rotation of the planet and its ring thus appear to be the same.

Q. What is the supposed use of the ring of Saturn?

A. The same as the satellites—to supply it with light, so essential in a planet so remote from the sun.

Satellites of Saturn.

Q. By how many satellites is Saturn attended?

A. Seven. Their distances from Saturn vary from upwards of 130,000 miles, the distance of the nearest, to 2,460,000 miles, that of the most remote. Their times of revolution are, from 22 hours, the period of the nearest, to 79 days, the period of the most distant. The latter is the largest, and is believed to be of greater magnitude than the planet Mercury. They are considered to revolve on their axes in the same period which each requires for its revolution round the planet.

(11.) *The Planet Uranus,* ♅.

Q. What is Uranus' position in the solar system

A. This is the most remote of the planets, at present known, from the sun. It is rarely and with difficulty seen by the naked eye, and was not discovered till very recently.

Q. By whom was this planet discovered ?

A. By the celebrated astronomer, Sir William Herschel, on the 13th of March 1781. It was called by him "Georgium Sidus," in honour of George III., and by some astronomers, "Herschel," in honour of its discoverer.

Q. What is the mean distance of Uranus from the sun ?

A. About 1,819,000,000 (eighteen hundred and nineteen millions) miles,—more than 19 times the distance of the earth from the sun.

Q. Does the distance of Uranus from the sun vary much ?

A. About the same in proportion as Jupiter. The excentricity of Uranus is less than 1-20th of its mean distance.

Q. Of what magnitude does the sun appear at Uranus ?

A. The sun's diameter appears at Uranus about 1-19th of its apparent magnitude at the earth,—as $1\frac{2}{3}$ to 32.

Q. What proportion of the sun's influence does Uranus receive ?

A. About 1-361st of that enjoyed by our earth.

Q. What is the diameter of Uranus ?

A. Nearly 35,000 miles.

Q. In what period does Uranus perform his orbit round the sun ?

A. In 30,686 days,—about 84 years:—moving in his orbit at the rate of 4 miles in a second, or 240 miles per minute.

Q. What angle does the orbit of Uranus form with the plane of the ecliptic ?

A. A very small angle, only 0° 46′ 26″: the two planes are thus more nearly coincident than in the case of any other of the planets.

Satellites of Uranus.

Q. By how many satellites is this planet attended ?

A. By six. Two of these present some very

markable peculiarities and departures fro
order in the solar system. Their orbits ar
pendicular to the ecliptic and to the orbit o
and they do not move in the same dire
prevails every where else in the solar syster
west to *east*; but from *east* to *west*.

III.—COMETS.

Q. What are comets?

A. Stars which appear at times in the sk
parts of the heavens, describing an apparen
course when compared with the planets,
very near to the sun, and again receding to
tance from it, and disappearing.

Q. What appearance do they present?

A. They appear under very various aspec
there is a brilliant luminous point called
the *coma* or hair is the more diffuse light
the nucleus; these two constituting the *hea*
is often present, though not always, a long l
pendage called a *tail*: this is always turned

Q. What are the comets supposed to be

A. They are regarded as consisting o
vaporous matter, or solid nuclei surround
vaporous matter, revolving round the sun i
gated ellipses, so that at one time they are
earth and sun, and at another very remot
bodies.

Q. Does not the tail frequently vary in

A. Yes; it enlarges as the planet approa
is most developed after it has passed the su
diminishing as the distance from the sun i
the influence of that body becomes less.
some comets have been estimated at up
millions of miles in length.

Q. From what is it inferred that the co
composed of matter in the aerial form?

A. In the comets, the smallest stars
distinctly seen through portions of their
they have been found to cause no sensib
of the motions of some of the satellites

ve passed near, while they themselves have been
d from their course: indications that their mass
l, and, as their bulk is considerable, that they
bably in the aerial state. Also, they present no
which seems to show that the sun's light pene-
heir substance, and that light is reflected from
part of it.

Have the periods of time which any of the comets
e for their revolution round the sun been calculated?

Yes. The periods of Halley's comet, the comet
cke, and the comet of Biela, have been com-
and the correctness of the calculation proved by
return several times.

ery bright comet, seen by the celebrated astronomer
y, in 1682, was calculated by him to be the same
h had appeared in 1531 and 1607,—at intervals of
een seventy-five and seventy six years. He ac-
ngly predicted its return about 1759, when it did
ar, nearly about the calculated time; and it has again
ned at the computed period, in 1835.

ne other two comets whose periods have been as-
ined return in short periods: that of Biela in
ars; that of Encke in 3⅓ years. These two comets
ot visible to the naked eye.

Has not the comet of Encke led to some singular
lations regarding the existence of a fluid spread out
gh space?

Yes. Its period of revolution round the sun is
l to be diminishing. This is attributed to the re-
ce opposed to it in its progress by some material
through which it passes,—which weakens its
ifugal force, gives the sun's attractive force larger
rtionate power, enables that body to draw it
r, and therefore into a smaller orbit, through which
forms its course in a shorter time.

NFLUENCE OF THE ATMOSPHERE ON ASTRONOMICAL APPEARANCES.

*How does the atmosphere produce any effect on
omical phenomena?*

A. By its power of *refracting* and *reflecting* the rays of light.

Q. What is meant by *refraction?*

A. Refraction, as applied to light, signifies the bending of the rays of light out of the straight line which they ordinarily pursue. This always happens when a ray of light passes *obliquely* from one medium to another; as when it passes from air to water, from water to air; from the ether, diffused through space, to the atmosphere by which the earth is surrounded; or from rarer to denser strata of the same medium.

Q. What effect does refraction produce on astronomical phenomena?

A. Owing to refraction, no heavenly body is seen in its true place, or of its true form, unless it be in the zenith. Every where else bodies appear to be higher than they really are.

Q. Explain how this takes place.

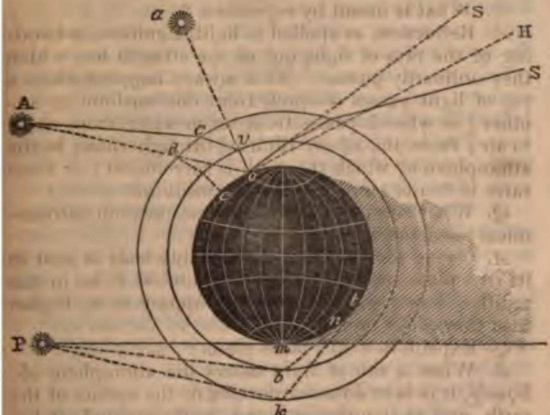
A. When a ray of light enters the atmosphere *obliquely*, it is bent downwards towards the surface of the earth, and as it proceeds nearer to the ground, it becomes more and more bent, in passing from the rarer strata above to the denser medium below. Now the object is seen by the observer in the direction which the ray has when it strikes upon the eye. Accordingly, as refraction bends the ray out of the slanting into the perpendicular direction, the object will be seen in a direction more perpendicular to the surface than its real one—that is, nearer the zenith, or more elevated above the horizon than it should be.

The following figure will illustrate this.

Let *o* represent a point on the earth's surface, and A any star or heavenly body. It is seen by means of rays of light from it which reach the eye. When the ray from A enters the atmosphere at *c*, it is refracted, and continues to be further refracted as it passes downwards, till, on reaching the surface, it has the direction *v o*. Accordingly, it is seen as if it were in this direction, which represents it not at A, but at *a*.

Q. Is refraction the same at different elevations?

Fig. 6.



A. No; it increases as the body is nearer the horizon, as the rays then pass through thicker and denser strata of air.

Q. Does refraction produce any other effect besides elevating the apparent situation of the heavenly bodies?

A. It actually brings into view bodies below the horizon, which would otherwise be invisible. This will be evident by inspecting the above figure, where it is seen that the body S, which is below the horizon H*o*, of a spectator at *o*, and would therefore be invisible to him without refraction, is brought into view, being made to appear at *s*, above his horizon.

Q. What effect will this produce upon sunrise and sunset?

A. It will raise the sun above the horizon in both cases, and thus cause him to rise earlier and set later than he otherwise would, shortening the period of darkness.

Q. Does refraction produce any other effects on the appearances of the celestial bodies.

A. It distorts the figures of the sun and moon
near the horizon, rendering them of an oval for
flattened at the lower part. This is caused by th
rapid increase of refraction near the horizon, s
the lower margins of these bodies are much mo
vated than the upper, which shortens the perpen
diameter, and gives the figure an oval shape.

Q. What is meant by the *reflection* of light?

A. The bounding off of a ray of light from
body on which it strikes.

Q. How does this affect astronomical phenom

A. The atmosphere reflects and disperses in
ections the rays of the sun. Were it not for this
tive power of the air, those bodies only would be
to us which receive the direct rays of the sun
by its reflective and dispersive power, bodies
light though not in the direct course of the sun'
and thus, as the atmosphere is every where, bod
visible to us in almost every situation.

Q. To what is TWILIGHT owing ?

A. Twilight is the faint and gradually dimi
light which we enjoy for a considerable time a
sun has sunk below the horizon. We are indeb
twilight to the reflective power of the atmo
The upper strata of air receive the sun's ray
considerable time after he has set to a point on t
face; accordingly that point will receive an inferi
reflected from them. And as it will receive re
light from a less body of air as the sun sinks lo
low the horizon of the place, this light will di
gradually till total darkness supervenes.

This is illustrated by the above figure, at the
part, where it will be observed that the parts
which are completely in the shade so far as th
direct influence is concerned, are yet enlightened
reflected from the upper regions of atmosphere
lie a little nearer to the sun.

Q. Why is the duration of twilight so short
pical regions ?

A. The rapid rotation of the parts there
great distance from the axis, bring very

mass of solid earth between the sun and the spectator, so that the period of reflection is cut short.

PARALLAX.

Q. What is meant by parallax?

A. In astronomy it is used in two senses—a special and a general one. In the special sense, it signifies the difference in the altitude of a celestial body as seen from the surface or from the centre of the earth—the point to which the positions of celestial objects are referred.

Q. What is the more general meaning of the term *parallax*?

A. Parallax, in the wider acceptation of the term, signifies the apparent change in position of an object, arising from a change in the position of the observer, sometimes termed its *parallactic motion*,—and expressed in another way, by *the magnitude of the angle formed at the object by the two lines drawn from the object to the two points from which it is observed.*

If an individual walk along a road for any given distance, and take some very remote object, such as the stars, or a tower or mountain, whereby to judge of the apparent motions of bodies between his line of motion and the fixed objects by which he judges of their apparent motions, he will find that these various bodies will have shifted their apparent position less and less according as they are further from him,—that is, their *parallax* will be less. In proportion as they are more remote, he will find the angle at the body, formed by two straight lines drawn to the two points of view, become less and less, till it disappears, and the two lines coalesce; then there is no parallax, and *no means of measuring the distance of the object.* This is the case with any short distance on earth, such as that between two parallel streets, and the moon. The angle of parallax disappears, the two lines from these streets to the moon coalesce, the moon appears in the same position along either street, the distance between the two positions is too short to give an angle at th moon; and we could not, therefore, with that distance as a basis, measure the moon's distance from us.

It is the same with the fixed stars,—the longest basis we can command, viz. the diameter of the earth's orbit, or 190 millions of miles, occasions no parallactic motion in any of the fixed stars,—gives no angle at any of them with which it has yet been tried. That enormous distance shrinks to a point compared with the distance of the nearest fixed star; and we have therefore no basis with which to determine their actual distance.

DAY AND NIGHT—SEASONS.

Q. What is the cause of the alternate changes from darkness to light, termed *night* and *day?*

A. The sun enlightens only that half of the earth which is turned towards him, the other half being in darkness; and as the earth, by its rotation on its axis, presents every part of its surface successively to the sun, each part will have an alternation of darkness and light.

Q. Why is the length of day and night different at different periods of the year?

A. This arises from the earth moving annually round the sun; from the axis of the earth being inclined to the plane of its orbit round the sun; and from that axis being parallel to itself in all parts of its orbit.

Q. Explain how this causes an increase in the length of the day over that of the night.

A. As the north pole of the earth leans towards the sun at one period of the year, the line between the dark and illuminated part, called *the terminator*, will then be beyond that pole; in revolving, that pole and the parts around it, between it and the terminator, will never be out of the illuminated part, and there will be constant day there: and the parts farther south will describe more than half of their daily circle *without* the dark part, and therefore will have longer day than night. The excess of the portion without the dark part will gradually diminish as they are farther south, till, at th equator, an equal portion will be passed on each side the terminator, and there will be equal night and d

Q. When the north pole is farthest inclined to the sun, how far will the terminator be beyond that pole?

A. Twenty-three degrees and twenty-eight minutes —23° 28′; as shown in Fig. 7., where N is the north pole, and *d* the terminator, at a distance of about 23½° from N, for N*d* is about the fourth part of NA, which is the fourth part of the whole circle, or 90°.

Q. How far then will the region of perpetual day extend?

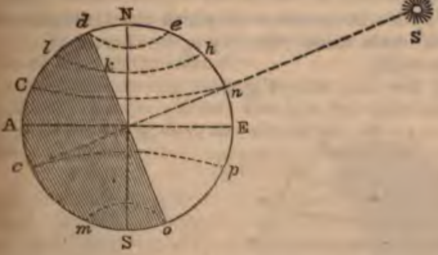
A. To all parts within 23° 28′ of the north pole,—that is, to all parts within the arctic circle.

Q. And how far south will the day be longer than the night?

A. To the equator: there, the days and nights are always equal—equal parts of the time of rotation being spent without and within the terminator.

This will be better understood by referring to the following figure, which illustrates what has been described:

Fig. 7.



Let ANES represent the earth, N the north pole, S the south pole, NS the axis about which it turns, and AE the line of the equator; S, at the right, the sun, *dAo* the part of the earth not receiving the sun's light, *do* the line of the terminator. It will be seen from the position of the sun that the north pole is turned towards it, and the south pole turned from it. Any point in revolving will take twelve hours in passing from one side of NS to the other, as from *e* to *d*, or *n* to C, and

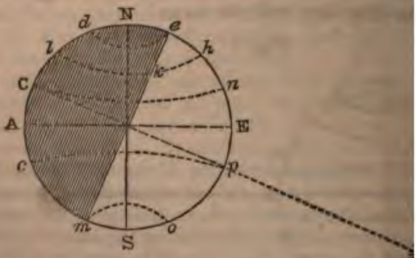
twelve hours in returning again : and the mi
of each twelve hours will be where it crosses

It will be at once evident, that any point
and *e* will never be out of the sun's light, an
must have constant day ; that any point from
in revolving, will be more than half of the pe
out the terminator ; that it will be a less pr
its course without the terminator as it is furth
that E will spend half of its course without t
ator, as that circle cuts EA, the circle in w
volves, exactly in the middle.

The point *h*, for instance, revolving in tw
from *h* to *l*, will have *h* for its mid-day or n
nearest to the sun ; the point *k*, where the li
the terminator, for sunset ; and *l* for midnig
period from noon to sunset is longer than
sunset to midnight, so likewise the period fron
noon will be longer than that from midnight
—and the whole day of that point will be l
its night.

Q. Explain the manner in which the inc
the earth's axis causes the day to be shorte
than the night.

Fig. 8.



A. This occurs to us when the north p
from the sun, as exhibited in Fig. 8 :
will be to place that pole, with respect to
of the earth's surface, in exactly the

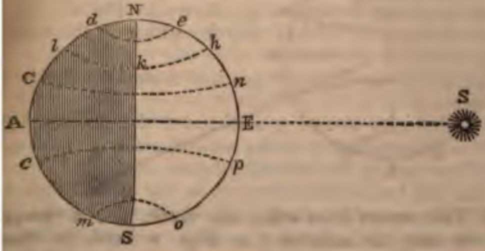
which it formerly occupied with respect to the illumined part.

The same letters indicate the very same parts as in the former figure, excepting the terminator, which is now from *e* to *m*, enveloping in darkness the north pole and the regions around it in every direction for 23° 28′ from the pole. Within the arctic circle, therefore, there will be perpetual night. From that circle to the equator, any point, in its daily rotation, will pass from noon to the terminator before it has gone through half of its circle, and will therefore have longer night than day. It will be enveloped in darkness sooner after noon, and have longer night, in proportion as it is nearer to the pole. And as the terminator *em* still cuts the equator EA in two equal parts, there will be equal day and night at the equator. Thus, the same point *h*, is seen to pass to the point *k*, where it meets the terminator, in less than 6 hours, and to be more than 6 hours in revolving from *k* to *l*, its midnight: from midnight to sunrise will also be more than 6 hours, and its whole night must be greater than its day.

Q. How are the opposite poles and parts on the other side of the equator affected?

A. Exactly in the reverse manner; as will be seen in Figs. 7. and 8. When one has the short day, the other has the long day, and *vice versa*.

Fig. 9.



Q. Is there not part of the year when night and day over all the world?

A. Yes. This is represented in the pr where the terminator is seen in the sa earth's axis, crossing the equator at right

In this figure it is evident that each illumined half, NES, in revolving from th to NAS, its midnight, will cross the term half way between these two times—that is, i same will take place in passing from NAS and the night and day must therefore be

Q. At what periods of the year do th the length of the day and night occur?

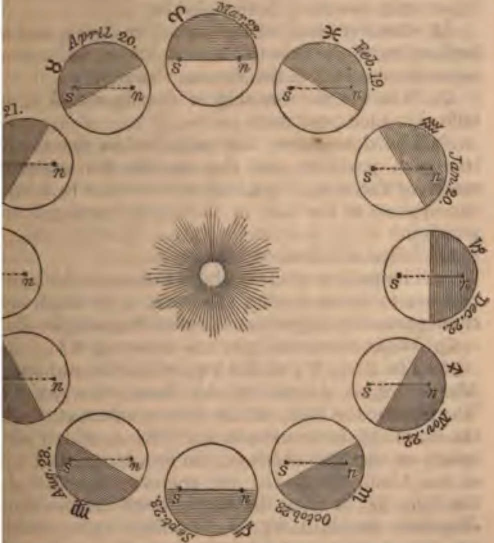
A. The north pole is turned towards fully on the 21st of June, when the turned from the sun; and it is therefore of the equator, and short day south of shown in Fig. 7. From this position the e changes till each pole is equally turned to the terminator coincides with the earth's is equal day and night over all the eart place on the 23d of September, and is tumnal *equinox.* From this the earth gra the position shown in Fig. 8., with the no from the sun, the south pole towards it: day north of the equator, and long da This takes place on the 22d of Decemb then passes to a position exactly analogou it occupied on September 23, shown in it reaches on the 22d of March, which *equinox.*

Q. How does the earth get into these tions?

A. From its annual course round th poles always pointing in the same direct be illustrated by the following figure:—

Let the twelve circles represent the different parts of its course round the s *ns* represent the axis of the earth, *n* pole, *s* the south pole. The termina

Fig. 10.



ndicular to the sun's rays, and varying its position
respect to the axis *ns*, which is observed to point,
the twelve positions, always in the same direction.
figure is a mixture of *plan*, *section*, and *perspec-*
and almost the only method, by a drawing, of
g a clear view of the effect of the earth's motion
l the sun, on the relation of the terminator to the
rent parts of its surface.

the right is seen the position on December 22, the
pole quite within the dark half, the south en-
without it: at the top is seen the position on
h 22, the terminator passing through the north
uth poles: at the left is seen the position of the
on *June* 21, the north pole entirely in the sun's
the south pole entirely in the shade: and at the

bottom is seen the position on Septemb
nator again touching both poles.

An attentive study of the preceding
inclination of the axis to the terminato
vey a precise idea of the various chang

Q. What is the meaning of the sig
tached to each position?

A. The date shows the period whe
into each position; and the sign is
mark for the *sign*, or part of the heav
sun appears at the time of the earth e
position.

Q. What are these signs?

A. The path or circle of the heavens,
appears to move during the year, is
equal parts of 30 degrees each, called SIG

Q. What names are given to these s

A. The first, ♈, at the top, which
March 22, is ARIES, or the Ram;
TAURUS, or the Bull, which the sun en
the third, ♊, is GEMINI, or the Twins
enters on the 21st of May; the fourth,
or the Crab, which the sun enters on
the fifth, ♌, is LEO, the Lion, which
July 23; the sixth, ♍, VIRGO, the V
sun enters on August 23; the seventh
Balance, which the sun enters on Sep
eighth, ♏, SCORPIO, the Scorpion, whi
on October 23; the ninth, ♐, SAGITTA
which the sun enters on November 22
CAPRICORNUS, the Goat, which the su
cember 22; the eleventh, ♒, AQUARIU
which the sun enters on January 20;
PISCES, the Fishes, which the sun enters

Q. These seem to be the names
Do the signs and constellations of
correspond?

A. No. Owing to a conical moti
axis, the sun does not now enter t
the same periods as formerly. Bu
constellations have still been retai

signs (*i. e.* the parts of the heavens) which the sun enters at the same periods.

Q. How much has the sun moved from the former signs?

A. A whole sign, or 30 degrees; so that the *sign* ARIES is now in the *constellation* PISCES; the *sign* TAURUS in the *constellation* ARIES; the *sign* GEMINI in the *constellation* TAURUS; and so on.

This retrograde motion of the signs is termed the *precession of the equinoxes.*

Q. Why is the sun represented in different positions in Figs. 7, 8, and 9?

A. The effect of the earth's motion round the sun is to make the latter appear to oscillate backwards and forwards between the highest and lowest position shown in these figures; that is, from being perpendicular to the parallel of latitude called the Tropic of Capricorn, *cp*, 23° 28′ south of the equator, on December 22,—to being perpendicular to the Tropic of Cancer, C*n*, 23° 28′ north of the equator, on June 21,—from *a* to *o*, Fig. 2. page 13, and then back from *o* to *a*. At the former of these periods he appears highest above the horizon to those south of the equator: at the latter, highest to those north of the equator.

Q. What are these periods termed?

A. SOLSTICES.—December 22, the winter solstice,—June 21, the summer solstice,—to those of the northern hemisphere.

Q. Why are they termed solstices?

A. Because the sun appears to stand still for a little at these two periods, ceasing to ascend or descend further,—apparently pausing before he retraces his course.

Q. Do these changes in the relative position of the earth and sun produce any influence on the state of the weather at different times?

A. Yes; they give rise to the change in the Seasons?

Q. How do these changes take place?

A. The sun imparts more heat in proportion, 1. as he *is higher above* the horizon of a place and his rays fall *more perpendicularly*, and 2. as he is a longer time above *the horizon.* As this takes place to us between Marc and September, we have summer then: from ber to March, the sun's rays fall in a more slan rection, and he is a shorter time above the hori have winter then.

Q. What is the state of the southern hen then?

A. Exactly the reverse of the northern: during our winter—winter during our summer.

Figures 7. and 8. will illustrate this. In Fig sun's rays will fall more perpendicularly on th north of the equator than on the parts south of th and at the same time the days will be longer in mer: there will therefore be summer in the n regions; winter in the southern.

Exactly the reverse is shown in Fig. 8.

Q. But the greatest heat is not when the sun est and longest above the horizon, nor the grea when the sun is lowest, and the day shortest, b a month after these times.

A. This is caused by the circumstance, that takes its temperature chiefly from the earth; and heat accumulates in the earth, which still grows so long as it receives more during the day than with during the night, which continues to about of July; and grows colder, so long as it pa more heat during the night than it receives du day, which continues till about the end of Jan

Q. Since we are nearer the sun in winter summer, how is it that we are not much warm former period?

A. This makes no difference; for, as much lost by our more rapid motion during wint gained by our greater proximity to the sun t *vice versa* in summer.

THE MOON'S PHASES—ECLIPSES—T

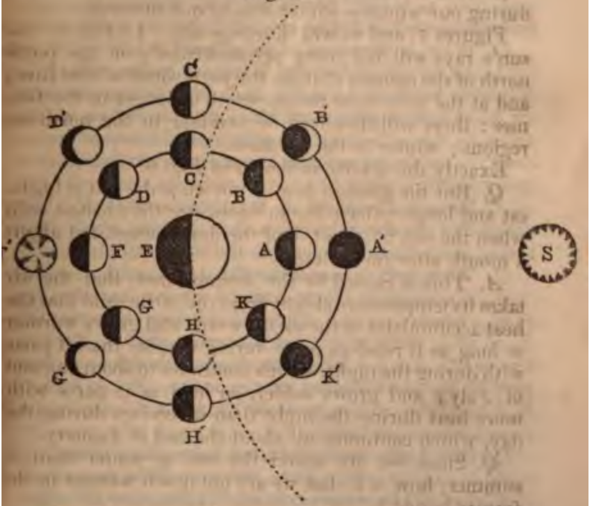
Q. What is the cause of the different appea the moon at different times?

A. These changes in the moon's appearanc

PHASES. They are caused by the moon being a dark body, shining only by reflecting the sun's light, and by her motion round the earth, so that different quantities of the illuminated half are turned towards the earth at different parts of her course.

The following figure will illustrate the moon's phases.

Fig. 11.



Let S represent the sun, E the earth, and A, B, C, D, F, G, H. K, in the inner circle, the moon, revolving in the direction of the order in which the letters have just been named. Then at A, the side illuminated by the sun being turned from the earth, the moon will present its unenlightened half to the earth, and will not be seen. At B, as is seen by the points where the inner circle cuts the moon, part only of the enlightened half is towards the earth: the greater part of the half turned to the earth is dark, and the moon will appear as at B′ in the outer circle. At F, the enlightened side is turned towards the earth, and the moon appears full, as at F′. By tracing the figure, the phases will be readily understood: the inner circle shows the illuminated and dark parts—the outer circle the appearance presented to the earth.

Q. What is meant by an ECLIPSE?

A. The sun or moon being darkened for a time by a shadow which gradually comes on, covers the surface, and then as slowly passes off, and restores the body eclipsed to its full light.

Q. What is the cause of an eclipse?

A. An eclipse of the sun is caused by the moon interposing between the earth and sun, so that she cuts off or eclipses a portion of his light: an eclipse of the moon, by the earth interposing between the sun and moon.

Q. Why do not eclipses occur whenever there is new moon and full moon?

A. Because the plane of the moon's orbit does not coincide with the ecliptic, so that the sun, earth, and moon, are not often exactly in the same straight line.

Q. What is the cause of the phenomena of the TIDES?

A. The attractive force exerted by the moon on the earth, which has the effect of drawing towards the moon those parts which are moveable, that is, the waters of the ocean. They rise highest therefore at that part of the earth nearest to the moon, giving *full* or *high tide*, and are drawn from the parts situated sideways towards the moon.

Q. But high water does not take place when the moon is exactly over a place, but some little time after?

A. Yes. The waters continue to rise after the moon has exerted its strongest action upon them, obeying the impetus they have received.

Q. Is there not also high water on the side of the earth furthest from the moon?

A. Yes. There are two high tides daily:—on the parts of the earth nearest to and most remote from the moon,—and two low tides daily, at the places on each side intermediate between these two. At the part most remote from the moon, her action will be least, and the waters will therefore be higher there than at the sides, where, from being nearer, she acts with greater effect.

Q. Does the sun influence the tides?

A. Yes: they are highest when his action is conbined with that of the moon, at new and full moon: owest or *neap* when he acts in opposition to her, *i. e.* when the moon is half full, as at C and H, Fig. 11.

DIVISIONS OF TIME.

Q. What period of time is taken as the standard in the reckoning of time?

A. The mean solar day of 24 hours,—that is, the mean time which the earth takes in revolving from the moment when the sun is on the meridian of a place till he returns to that meridian again.

Q. Does not the same time always elapse between two successive appulses of the sun to the meridian?

A. No. In consequence, 1. Of the inclination of the earth's axis to the plane of its orbit, and 2. Of the inequality in its rate of motion round the sun, this period varies in duration at different times of the year.

Q. What term is applied to the difference between the mean and actual solar day?

A. The "Equation of Time."

Q. Are the mean and actual solar day ever the same?

A. Yes: Four times a-year,—on the 24th of December, 15th of April, 15th of June, and 1st of September, the mean solar day and the actual solar day are the same; or the clock (mean solar day) and sun-dial (actual solar day) are coincident.

Q. These periods seem near the equinoxes and solstices. Why do they not coincide with them?

A. Did the variation in the solar day depend solely on the inclination of the earth's axis to the ecliptic, the periods of the clock and sun being the same would be the equinoxes and solstices; but the other element which occasions variation in the solar day,—namely, the inequality in the rate of the earth's motion round the sun, —causes the time of coincidence of clock and sun to vary from the equinoxes and solstices.

Q. At what times is the mean solar day shorter than he actual solar day?

ery common year, which leaves no remainder
ided by 4, as 1840, and every hundredth year,
ves no remainder when divided by 400, as
leap year—of 366 days. All the others are
65 days.

whom was this arrangement introduced?
Pope Gregory XIII.; and it has been adopted
ized countries, excepting Russia.
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accumulated to 11 days, and was rectified
ing the days of the month 11 days. The difween the new and old styles is now 12 days.

HISTORICAL SKETCH.

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fter the birth of Christ. He considered that
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which they have just been enumerated.
med the PTOLEMAIC SYSTEM.
is the theory of epicycloids?
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ich moves round the earth in the circu

[illegible] and from June
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[illegible] mean time.

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In what periods is the [illegible] solar day ?

[illegible] April 15 to June 15, and from September
[illegible] the actual solar day is shorter than
[illegible] the sun takes less than 24 hours
[illegible] appulses to the meridian,—ap-
[illegible] mean time,—or *the clock is behind*
[illegible] Equation of Time in the almanacs.
[illegible] may be said that, from the time
[illegible] behind the sun ; from the
[illegible] is before the sun.

[illegible] day of 23 hours 56 min.

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[illegible]

[illegible] the year?
[illegible] the sun
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[illegible]

A. Every common year, which leaves no remainder when divided by 4, as 1840, and every hundredth year, which leaves no remainder when divided by 400, as 2000, is a leap year—of 366 days. All the others are years of 365 days.

Q. By whom was this arrangement introduced?

A. By Pope Gregory XIII.; and it has been adopted in all civilized countries, excepting Russia.

Q. When was it introduced into Great Britain?

A. In 1752,—being termed the *new style.* The error had then accumulated to 11 days, and was rectified by advancing the days of the month 11 days. The difference between the new and old styles is now 12 days.

HISTORICAL SKETCH.

Q. Who were the first cultivators of the science of Astronomy?

A. The Chaldeans, Chinese, Indians, and Egyptians. The Phœnicians and the Greeks followed.

Q. By whom was the present view of the solar system first promulgated?

A. By PYTHAGORAS, a Grecian philosopher, who flourished about 500 years before the Christian era. He supposed that the earth revolves daily on its axis, and annually round the sun.

Q. Was this opinion generally entertained?

A. No. It was confined to *some of* the learned, and not even confidently taught or firmly believed by them.

Q. What notion was entertained by the people?

A. That the sun, moon, and planets, revolve daily round the earth, which was supposed to be fixed. This system, with the theory of epicycloids, was afterwards taught by PTOLEMY, an Egyptian philosopher, about 130 years after the birth of Christ. He considered that the moon, Mercury, Venus, the sun, Mars, Jupiter, and Saturn, revolved round the earth, at distances in the order in which they have just been enumerated. This was termed the PTOLEMAIC SYSTEM.

Q. What is the theory of epicycloids?

A. That each planet revolves in a small circle, the centre of which moves round the earth in the circumference of a large circle; this theory had been devised by Apollonius to explain the slow and retrograde movements of the planets, and their being sometimes stationary.

Q. How was the constant vicinity of Mercury and Venus to the sun,—their never being seen in opposition,—explained?

A. It was supposed that while the moon, the sun, Mars, Jupiter, and Saturn, revolve round the earth, Mercury and Venus revolve round the sun as their centre.

Q. Did not Hipparchus render essential service to the Science of Astronomy?

A. Yes. This philosopher, who flourished about 150 B. C., determined with greater accuracy the length of the year, and inequality of the sun's rate of motion, drew up a catalogue of the fixed stars with their precise positions, discovered the precession of the equinoxes, &c.

Q. How long did the Ptolemaic remain the received system of Astronomy?

A. Till 1543, when the true or Pythagorean system was revived by COPERNICUS, a native of Poland, born in 1473. As this system had been so long rejected, COPERNICUS is usually spoken of as its founder; and it is called the Copernican system.

Q. By whom was the Copernican system supported and confirmed?

A. By GALILEO, KEPLER, HUYGENS, HALLEY, SIR ISAAC NEWTON, &c. KEPLER developed the three laws pointed out, by inverted commas, in pages 27-8-9, and Sir ISAAC NEWTON, in the theory of universal gravitation, furnished a key to the whole system, by which known phenomena were explained, and previously unknown phenomena detected.

Q. What was the system of TYCHO BRAHE?

A. This distinguished Dane, who flourished about 1586, whose observations contributed so much to the advancement of astronomical science, supposed that the moon and sun revolve round the earth as their centre, and that the planets revolve about the sun as their centre. This was termed the Tychonic system.

THE END.

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